The Faculty of Engineering and Science
The Study Board of Electronics and IT


# Curriculum for
# Bachelor (BSc) in Robotics

Aalborg University
September 2014

Campus Aalborg

**Preface:**
Pursuant to Act 367 of May 22, 2013 on Universities (the University Act) with subsequent changes, the following curriculum for the Bachelor's programme in Robotics is established. The programme also follows the Framework Provisions and the Examination Policies and Procedures for the Faculty of Engineering and Science and The Faculty of Medicine.

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# Chapter 1: Legal Basis of the Curriculum, etc.

### 1.1 Basis in ministerial orders
The Bachelor's programme in Robotics is organised in accordance with the Ministry of Science, Innovation and Higher Education's Order no. 814 of June 29, 2010 on Bachelor's and Master's Programmes at Universities (the Ministerial Order of the Study Programmes) and Ministerial Order no. 666 of June 24, 2012 on University Examinations (the Examination Order) with subsequent changes. Further reference is made to Ministerial Order no. 1488 of December 16, 2013 (the Admission Order) and Ministerial Order no. 250 of March 15, 2007 (the Grading Scale Order) with subsequent changes.

### 1.2 Faculty affiliation
The Bachelor's programme falls under the Faculty of Engineering and Science, Aalborg University.

### 1.3 Board of Studies affiliation
The Bachelor's programme falls under the Board of Studies for Electronics and IT at the School of Information and Communication Technology.

# Chapter 2: Admission, Degree Designation, Programme Duration and Competence Profile

### 2.1 Admission
Admission to the Bachelor's programme in Robotics requires an upper secondary education.

The program's specific requirements are: English B, Mathematics A and Physics B according to admission notice. All subjects must be passed.

### 2.2 Degree designation in Danish and English
The Bachelor's programme entitles the graduate to the designation Bachelor (BSc) in robotics. The Danish designation is Bachelor (BSc) i teknisk videnskab (robotteknologi).

### 2.3 The programme's specification in ECTS credits
The Bachelor's programme is a 3-year, research-based, full-time study programme. The programme is set to 180 ECTS credits.

### 2.4 Competence profile on the diploma
The following will appear on the diploma:

A graduate of the Bachelor's programme has competencies acquired through an educational programme that has taken place in a research environment.

A graduate of the Bachelor's programme has fundamental knowledge of and insight into his/her subject's methods and scientific foundation. These properties qualify the graduate of the Bachelor's programme for further education in a relevant Master's programme as well as for employment on the basis of the educational programme.

### 2.5 Competence profile of the programme:

<u>The graduate of the Bachelor's programme:</u>

| | |
|---|---|
| Knowledge | • Has knowledge of and insight into fundamental theories, methods, tools and practical subjects within the fields of |

| | |
|---|---|
| | Robotics<br>• Has a firm grasp of the mathematical and programming technical foundations of the field<br>• Has knowledge of the interaction between electronic and mechanical systems, including feedback mechanisms, electromechanical systems, software and manipulators<br>• Has knowledge of sensors and actuators relevant for the field |
| Skills | • Can utilize up-to-date scientific methods, tools and techniques to analyse and solve complex problems in the fields of robotics<br>• Can evaluate and compare theoretical and practical problems, as well as describe and select relevant solution strategies<br>• Is able to implement such solution strategies and evaluate their success in a systematic manner<br>• Is able to present problems and solution strategies within the fields of robotics, in writing as well as orally, to specialists as well as non-specialists in the fields, including external parties, users, etc. |
| Competencies | • Is able to handle complex situations that arise in research and/or development-related environments, such as university studies and/or engineering workplaces.<br>• Is able to develop and test robotics hardware and software and integrate them into a broader systems-oriented context<br>• Can work independently as well as in collaboration with others, both within and across technical fields, in an efficient and professional manner<br>• Is able to identify his/her own learning needs and structure his/her own learning in various learning environment |

## Chapter 3: Content and Organisation of the Programme

The programme is structured in modules and organised as a problem-based study. A module is a programme element or a group of programme elements, which aims to give students a set of professional skills within a fixed time frame specified in ECTS credits, and concluding with one or more examinations within specific exam periods. The examinations are defined in the curriculum.

The programme is based on a combination of academic, problem-oriented and interdisciplinary approaches and organised based on the following work and evaluation methods that combine skills and reflection:

- lectures
- classroom instruction
- project work
- workshops
- exercises (individually and in groups)
- teacher feedback
- reflection
- portfolio work

**Overview of the programme:**

All modules are assessed through individual grading according to the 7-point scale *or* Pass/Fail. All modules are assessed by external examination (external grading) or internal examination (internal grading or assessment by the supervisor only).

| Semester | Module | ECTS | Assessment | Exam |
|---|---|---|---|---|
| 1st | Technological Teamwork | 5 | Pass/Fail | Internal |
| | Fundamental Mobile Robotics | 10 | 7-point scale | Internal |
| | Robot Programming | 5 | Pass/Fail | Internal |
| | Problem Based Learning in Science, Technology and Society | 5 | Pass/Fail | Internal |
| | Linear Algebra | 5 | 7-point scale | Internal |
| 2nd | Manipulators and Industrial Robotics | 15 | 7-point scale | External |
| | Robot mechanics, Modelling, and Simulation | 5 | 7-point scale | Internal |
| | Calculus | 5 | 7-point scale | Internal |
| | Structured System and Product Development | 5 | Pass/Fail | Internal |
| 3rd | Manipulating the Surroundings | 15 | 7-point scale | External |
| | Actuators, Drivers and Electronic Modules | 5 | Pass/Fail | Internal |
| | Robot Dynamics, Biomechanics and Biological Actuators | 5 | Pass/Fail | Internal |
| | Robotic Control Systems | 5 | 7-point scale | Internal |
| 4th | Sensing the Surroundings | 15 | 7-point scale | Internal |
| | Robotic Sensing | 5 | 7-point scale | Internal |
| | Robotic Perception | 5 | Pass/Fail | Internal |
| | Probability Theory and Statistics | 5 | 7-point scale | Internal |
| 5th | Robot Integration | 15 | 7-point scale | External |
| | Software and Automation Frameworks | 5 | Pass/Fail | Internal |
| | Productions Systems and Automation | 5 | 7-point scale | Internal |
| | Robots in the Health Care System | 5 | Pass/Fail | Internal |
| 6th | BSc Project (Robots in an Application Context) | 15 | 7-point scale | External |
| | BSc Project (Robots in a Theoretical Context) | 15 | 7-point scale | External |
| | Elective course, pre-approved list* | 5 | Pass/Fail | Internal |
| | Elective course, pre-approved list* | 5 | Pass/Fail | Internal |
| | Motion Planning and Path Planning | 5 | Pass/Fail | Internal |
| Total | | 180 | | |

*List include, “Matrix calculations and convex optimization”, “design of embedded software”, “Object Oriented Software Engineering”, “Digital design”, “Digital signal processing”, “Digital HW/SW systems”, and “Health technology from an organizational or business perspective”.

Throughout the semesters students will at an increasing abstraction level be introduced to relevant theories and scientific methods. Scientific theory and scientific methods in general are included in the course Problem based learning in science, technology and society. Moreover, the students develop their skills in this area in their project work, where they will apply scientific methods in practice and reflect on their application.

**Descriptions of modules**

**Title:** **Technological Teamwork (P0)**
*Teknologisk projektarbejde*

Semester: 1

Purpose: Through this module, the student shall acquire knowledge about problem oriented and problem based learning. Furthermore, he/she shall acquire first-hand knowledge about project-oriented group work as a learning method. Additionally, the student will be introduced to basic problems and concepts within the field of robotics.

Objectives: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have insight into elementary concepts related to project-oriented group work.
- Must be familiar with the processes involved in project work, knowledge acquisition and supervisor collaboration

Skills

- Must be able to define project goals and work in a methodical manner toward achieving such goals
- Must be able to describe and analyse several approaches to project solutions
- Must be able to present results achieved within the project in writing, orally, and graphically in a comprehensive manner.

Competencies

- Must be able to reflect upon the problem oriented and problem based learning approach taken throughout the study
- Must be able to document the results achieved during the project in a report
- Must be able to cooperate with other students during the project period and make a joint presentation of the results achieved in the project.
- Must be able to reflect upon different ways of presenting results achieved with the project in writing, orally, and graphically.

Content: The project group must prepare a report and process analysis, participate in a P0 collection of experience and attend a presentation seminar where the project group documents are discussed.

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Fundamental Mobile Robotics (P1)**
*Fundamental mobilrobotik*

Semester: 1

Purpose: A robot is a physical manifestation and mobile robots are one such example. The project takes its starting point in a problem of relevance to society or industry that may be addressed using mobile robotics; the problem is then broken down into smaller, more manageable sub-problems and analysed for the purpose of defining a relevant technical problem formulation, which can be solved via theories and methods related to robotic systems. The solution shall encompass a programmable computer, which is able to measure signals from its surroundings via selected sensors and process them digitally in some form and cause deliberate robotic action via the robots actuators, e.g. wheels. The software can run on the robot platform or remotely via a network.

Objectives: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have an understanding of fundamental robotic systems and their interaction with the environment
- Must have basic insight into concepts such as signals, sensors, mechanics, actuators and computers
- Must have sufficient insight into technological and social issues to enable them to pinpoint relevant problems that can be solved by technical means
- Must have knowledge about common processes in extensive, problem-oriented projects
- Must be able to explain and clarify theories and methods used in the project

Skills

- Must be able to identify relevant requirements to a technical solution, product or similar
- Must be able to follow a relevant method for structured development in the project, including formulation and analysis of the problem, define a requirement specification and divide the problem into sub-problems that can be resolved separately
- Must be able to formulate and solve technical problems via algorithms and be able to implement these algorithms in a programmable device the control the robot behaviour
- Must be able to analyse and evaluate their own utilization of theories and methods outlined above
- Must be able to document and present the knowledge and skills outlined above, using correct terminology, in writing as well as orally
- Must be able to analyse and evaluate their own learning processes using relevant methods
- Must be able to plan and carry out an extensive group project in collaboration with a supervisor

Competencies

- Must understand the general concept of a robot system, in

particular pertaining to computation and interacting with the surroundings
- Must be able to assume responsibility for their own learning processes during an extensive group project, as well as generalize and interpret the experience acquired
- Must be able to plan, structure, carry out, and reflect upon a project that starts from a socially or industrially relevant problem, in which robotic systems technology is an important element, individually as well as in groups.
- Must be able to demonstrate a working prototype of their robot

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3. A minimum of 5 semester lectures are given as support for projects. All groups on the semester participate. The objective is to introduce methodology and knowledge on fundamental robotics in the context of the specific robotics problems that the students are working on in their projects. Sensor and actuator hardware that is supported by ROS packages is introduced , and this serves as a foundation for problem solving in the project.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Robot Programming (C)**
*Robot programmering*

Purpose: Students who complete the module should be able to apply development robotic tools, programming languages and SW-environments for solving previously specified tasks in robotics.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have understanding of integrated development environments
- Must have understanding of differences between run-time and compile-time computer programming languages
- Must be able to explain the concepts of types, declarations, expressions and statements
- Must have insight into data structures, such as arrays
- Must have insight into input/output in various forms
- Must have understanding of procedures and functions, including function arguments
- Must have understanding of the complexity of a program
- General imperative programming language (such as C and Java)
- Software environments for robotic programming Robot Operating System (ROS)
- The use of ROS services and package abstractions of sensors, actuators and signals
- Must have understanding of the sharing and collaboration inherent to software frameworks such as ROS

Skills

- Must be able to interpret and analyse a basic procedural program and elaborate its functionality
- Must be able to design and implement algorithms for data structure manipulation
- Must be able to explain how to use algorithms, functions and data for solving problems (understanding)
- Must be able to apply at least one specific imperative programming to solve general information processing tasks
- Must be able to apply ROS for solving a specific robot programming task, given sensors and actuators supported by ROS packages

Competencies

- Must be able, individually and in collaboration with others, to design and implement one or more programs to solve a previously specified problems

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Problem Based Learning in Science, Technology and Society (C)**
*Problembaseret læring i videnskab, teknologi og samfund*

Purpose: To enable the student to approach real-life complex problems in a methodical manner, and to carry out project work, planning and documentation in a structured way.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must be able to explain basic learning theory
- Must be able to explain techniques for planning and management of projects
- Must be able to explain different approaches to problem-based learning (PBL), including the so-called Aalborg model based on problems that are part of a social and/or humanistic context
- Must be able to explain different approaches to analysis and assessment of problems and solutions within engineering, natural and health sciences from a theoretical, ethical, and societal perspective
- Must be able to explain how these methods can be applied within robotics

Skills

- Must be able to plan and manage a problem-based study project
- Must be able to analyze the project group's organization and cooperation in order to identify strengths and weaknesses, and suggest how cooperation in future groups can be improved based on this analysis
- Must be able to reflect on the causes and devise possible solutions to any group conflicts
- Must be able to analyze and evaluate their own study work and learning, in order to identify strengths and weaknesses, and use these reflections to consider further study and group work
- Must be able to reflect upon the methods used from a theoretical perspective
- Must be able to identify relevant areas of focus, concepts and methods to assess and develop technical solutions under consideration of the social and humanistic contexts that solution must be a part of

Competencies

- Must be able to take part in a team-based project
- Must be able to document and present work carried out in a project
- Must be able to reflect upon and develop his/her own learning
- Must be able to engage in and improve upon the collaborative learning processes
- Must be able to reflect upon his/her professional activities in relation to the surrounding community

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Linear Algebra (C)**
*Lineær algebra*

Semester: 1

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have knowledge about definitions, results and techniques within the theory of systems of linear equations
- Must be able to demonstrate insight into linear transformations and their connection with matrices
- Must have acquired knowledge of simple matrix operations
- Must know about invertible matrices and invertible linear mappings
- Must have knowledge of the vector space Rn and various subspaces
- Must have knowledge of linear dependence and independence of vectors and the dimension and bases of subspace
- Must have knowledge of the determinant of matrices
- Must have knowledge of eigenvalues and eigenvectors of matrices and their use
- Must have knowledge of projections and orthonormal bases

Skills

- Must be able to use computer software such as Matlab to solve linear algebra problems
- Must be able to apply theory and calculation techniques for systems of linear equations to determine solvability and to provide complete solutions and their structure
- Must be able to represent systems of linear equations using matrix equations, and vice versa
- Must be able to determine and apply the reduced Echelon form of a matrix
- Must be able to use elementary matrices for Gaussian elimination and inversion of matrices
- Must be able to determine linear dependence or linear independence of small sets of vectors
- Must be able to determine the matrix for a given linear transformation, and vice versa
- Must be able to solve simple matrix equations
- Must be able to compute determinants and could use the result of calculation
- Must be able to calculate eigenvalues and eigenvectors for simple matrices
- Must be able to determine whether a matrix is diagonalizable, and if so, implement a diagonalization for simple matrices
- Must be able to compute the orthogonal projection onto a subspace of Rn
- Must be able to solve separable and linear first order differential equations, in general, and with initial conditions

Competencies

- Must demonstrate development of his/her knowledge of, understanding of, and ability to make use of, mathematical theories and methods within relevant technical fields

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Manipulators and Industrial Robotics (P)**
*Manipulatorer og industrirobotter*

Semester: 2

Purpose: Through theoretical and practical work on a selected problem, the students acquire knowledge in robotics engineering discipline, as well as use appropriate methods to document that the problem has a relevant social context. The problem is analysed by decomposition into sub problems in order to formulate a technical problem that can be solved by using manipulators or industrial robotics that interact with the environment in one way or another. The complete solution is assessed with respect to the relevant social context. Compared to the first semester, this semester focuses more on the manipulators and industrial robotic aspects.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have gained experience with theories and methods of calculation and simulation of kinematics for robotic manipulators
- Must have acquired knowledge of methods for analysis of linear dynamic systems
- Must have knowledge of relevant coordinate systems and transformations used to describe robot kinematics
- Must have knowledge of recognized standards and terms for documentation of robotic systems
- Must be able to demonstrate knowledge of theory and method to the extent of being able to explain and justify the project's theory and methods, including both selection and de-selection.
- Must be able to use relevant terminology

Skills

- Must have understanding of basic theories behind manipulator components such as joints and motors.
- Must be able to identify, analyze and formulate issues within the discipline through the use of contextual and technical analysis methods
- Shall, based on the above, be able to create requirements and test specifications that enable the completed system to be tested rigorously
- Must be able to use mathematical theories and methods to analyze problems involving kinematics
- Must be able to program basic manipulator motion using forward and inverse kinematics
- Must be able to document and disseminate knowledge and skills with proper use of terminology, orally and in writing through a project report
- Must be able to analyze and reflect upon his/her own learning process using appropriate methods of analysis and experience from P0 and P1
- Must be able to analyze a technical-scientific problem under consideration of technological and societal contexts, and assess the technological and social consequences of proposed solutions.

Competences

- Must be able to demonstrate, independently and in groups, the ability to plan, organize, implement and reflect upon a project that is based on a

problem of relevance to society or industry, in which industrial robotics or manipulators play a central role

- Must have acquired, independently and in groups, the ability to obtain the necessary knowledge of a contextual as well as of technical nature, and be able to formulate models of limited parts of reality to such a level of abstraction that the models can be used in the design, implementation and test of a comprehensive system to meet given requirements
- Must be able to evaluate and take responsibility for science and technical solutions in a societal perspective.
- Must be able to generalize and reflect upon the experience with project planning and cooperation for the further study acquired during the project work
- Must be able to solve simple production tasks with an industrial robot.
- Must be able to demonstrate a working prototype of their solution

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Robot Mechanics, Modelling, and Simulation (C)**
*Robot kinematic, modellering og simulering*

Semester: 2

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Fundamental aspects related to robot kinematics
- Methods of how to make spatial description of objects
- Basic methodologies for kinematic modelling of robot manipulators
- Principles for kinematic robot simulation
- Transforming task description to robot movements

Skills

- Apply homogeneous transformation matrices to represent position and orientation of objects
- Setup the direct and inverse kinematics of a robot
- Design simple trajectory planners, including Cartesian and joint interpolators
- Program an industrial robot to carry out various production tasks
- Transform the task space descriptions to robot movements
- Simulate the kinematic behaviour of a robot

Competencies

- Must be able to program a robot so that the desired kinematic behaviour is obtained.
- Must be able to simulate the kinematics of a robot
- Must be able to solve simple production tasks with an industrial robot.

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions.

**Title:** **Calculus (C)**
*Calculus*

Semester: 2

Purpose: Calculus is the branch of mathematics that studies differential equations and operations such as integration. Differential equations, in turn, describe (among other things) how signals in electric circuits behave

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have knowledge on real functions of two or more variables.
- Must have knowledge of the trigonometric functions and their inverse functions
- Most have knowledge of Taylors formula and Taylor series
- Must have knowledge of complex numbers and roots in polynomials
- Must have knowledge of the complex exponential function, its characteristics and its connection with trigonometric functions
- Must have knowledge of curves in the plane (both rectangular and polar coordinates) and spatial parameterizations, tangent vectors and curvatures of such curves
- Must have knowledge of the Laplace transform and its use in relation to solving differential equations.

Skills

- Must be able to approximate functions via Taylor series
- Must be able to carry out differentiation of functions of more variables, and have a geometric understanding that allows solution of inhomogeneous second order linear differential equations.

Competencies

- Must be able to solve linear differential equations with constant parameters
- Must be able to solve coupled first order linear differential equations and inhomogeneous second order linear differential equations
- Must be able to give a geometric description of real functions in 2 and 3 variables

Type of instruction: Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Structured System and Product Development (C)**
***Struktureret system- og produktudvikling***

Semester: 2

Purpose: To give knowledge within methods to perform structured development of systems and products, which includes mechanical components, electronic components and/or software. Here in part methods for the analysis of requirements, concept generation and selection, system definition, decomposition of the system into subsystems, methods for determining the interfaces as well as testing and verification of the established system.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge
- Must be able to account for different methodologies of product design and development
- Must be able to account for the link between the development process and time scheduling
- Must be able to account for design methods for hardware, software and industrial production
- Must be able to explain demands and specifications in the development process
- Must be able to distinguish between prototype implementation, emulation and simulation
- Must be able to account for black box and white box test methods

Skills
- Must be able to develop a requirements specification for a robotic system through an analysis of customer needs
- Must be able to systematically develop and select solution concepts that satisfy requirements specification
- Must be able to identify critical elements of proposed solution concepts
- Must be able to formulate a plan for a project's continuation
- Must be able to formulate verifiable demands for the system and subsystems
- Must be able to formulate and argue for internal and external interfaces
- Must be able to plan and conduct tests and evaluations at sub-system and system level

Competences
- Must be able to define a system, divide it into sub-systems and to perform integration of the sub-systems
- Must have the ability to systematically develop new products, in particular new robotic systems
- Must be able to evaluate and assess the system verification according to the system demands

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Manipulating the Surroundings (P)**
*Interaktion med omgivelserne*

Semester: 3

Purpose: Many robots are manipulators acting in a known environment, e.g. industrial production. These manipulators often require great accuracy. This project deals with the challenges of manipulating robots and attached tools with the adequate accuracy. To obtain this an understanding of the dynamic characteristic and controller design are essential.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge
- Must have knowledge about the terminology with robotic manipulation
- Must be able to understand how a particular robotic system, for example the semester project of the student, interacts with the surroundings.

Skills
- Must be able to analyze a relevant problem and suggest a solution that uses theories and methods within mechanics, electronic modules, modeling and control.
- Must be able to identify constraints and assessment criteria for a concrete robotic solution.
- Must be able to design and implement a manipulator (or parts thereof).
- Must be able to evaluate the solution with respect to the afore mentioned assessment criteria

Competencies
- Must be able to design robotic mechanisms.
- Must be able to implement control systems using electronic modules as micro controllers.
- Must be able to develop linear models of the dynamic behavior of manipulators.
- Must be able to select relevant control methods and apply these in a robotic context.
- Must be able to communicate the above (using proper terminology), both orally and in a written report
- Must be able to demonstrate a working prototype of their robot

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Actuators, Drivers and Electronic Modules (C)**
***Sensorer, aktuatorer, driver og elektoniske komponenter***

Semester: 3

Objective: Students who complete the module should have knowledge about the various building blocks comprising an embedded/robotic control system. The acquired knowledge should be applicable for selecting appropriate components for the design of robotic control systems.

Students who complete the module should have the following knowledge, and skills:

Knowledge

- Must have knowledge of basic electronics: capacitor, diode, and transistor
- Must have knowledge of sensing possibilities: push buttons, potentiometers, photo resistors and force sensitive resistors
- Must have knowledge of limited number of actuators e.g. DC-motors, step-motors, linear actuators
- Must have an overview of the basic structure and behaviour of micro-controllers
- Must have understanding on using micro-controllers: interface to the computer, analog/digital input/output
- Must have understanding of circuit applications: DC filtering, circuit protection and amplifiers
- Must have knowledge of one particular micro-controller to the level of register-structure, special purpose registers (including timers), I/O including digital, drivers, interrupt channels (level/rising/falling), analog and digital outputs and PWM)

Skills

- To apply acquired knowledge for the design and implementation of robotic control systems

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions.

**Title:** **Robot Dynamics, Biomechanics and Biological Actuators (C)**
*Robot dynamik, biomekanik, og biologiske aktuatorer*

Semester: 3

Objective: Students who complete the module should have knowledge about the dynamics of the human body and robotic mechanisms. The acquired knowledge should be applicable for designing of industrial robots as well as servicing and rehabilitation robots.

Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must be able to account for key concepts about the human musculoskeletal system, such as cross-bridge theory, different types of muscle contractions, Force-Length-Velocity relationships and different type of joints
- Must be able to account for key concepts from musculoskeletal modelling, such as muscle redundancy, inverse dynamics based estimation of muscle forces and assumptions in these models
- Must be able to explain basic concepts of robotic mechanisms
- Must be able to explain the acceleration of a rigid body, linear and angular accelerations
- Must be able to account for the mass distribution of a rigid body
- Must be able to account for Newton and Euler's equation
- Must be able to explain a Lagrangian formulation of manipulator dynamics

Skills

- Must be able to formulate the dynamic equations of robotic mechanisms
- Must be able to simulate and analyse robot motion
- Must be able to apply musculoskeletal modelling techniques on problems within robotics and its interaction with humans.

Competencies

- Must have an in-depth knowledge of robot dynamics which is applicable to the design and control of robotic systems
- Must be able to analyse and select properly robotic mechanisms for desired motion
- Must be able to analyse and critically evaluate the differences and similarities between the biological and robotic movement and actuator system

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Robotic Control Systems (C)**
*Robot reguleringssystemer*

Semester: 3

Objective: Students who complete the module should have knowledge about basic control methodologies and be able to apply them to simple robotic control tasks.

Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must be able to explain the key functionality and system properties provided by a control system
- Must be able to explain input/output systems with disturbances and measurement noise
- Must be able to account for MIMO and SISO systems.
- Must be able account for the key differences between feed forward and feed back control
- Must be able to account for the concepts of stability and instability, including the concepts of poles and zeros for linear systems, the Nyquist stability criterion and root loci.

Skills

- Must have the ability to identify inputs, outputs and sources of disturbance in a simple robot control system
- Must have the ability to design simple robot control systems based on the acquired knowledge
- Must be able to apply stability analysis to simple robot control systems
- Must be able to apply control design techniques based on open loop characteristics including phase and gain margins
- Must be able to explain PID controllers and apply tuning

Competencies

- Must have the ability to apply relevant terminology from automatic control in the description of robot problems and solutions
- Must have the ability to systematically develop simple control system solutions

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions.

**Title:** **Sensing the Surroundings (P)**
***Automatisk sansning af omgivelserne***

Semester: 4

Purpose: In many situations the robot has to operate in a non-static environment, e.g., the robot is mobile or the objects the robot interacts with are in unknown locations and/or configurations. For the robot to be able to operate in such situations it needs to 1) be able to sense its (changing) surroundings and 2) react accordingly. This project module deals with exactly these two challenges.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have knowledge about the terminology with robotic sensing
- Must be able to understand how a particular robotic system, for example the semester project of the student, relates to similar system and the surrounding context

Skills

- Must be able to analyse a relevant problem and suggest a solution that uses theories and methods within the fields of robot sensing and perception.
- Must be able to identify constraints and assessment criteria for a concrete robotic solution, and (if relevant) its usefulness to society
- Must be able to synthesize, i.e., design and implement, a system (or parts thereof) using a relevant combination of sensing and perception for a concrete robotic scenario
- Must be able to evaluate such a solution with respect to the afore mentioned assessment criteria

Competencies

- Must be able to select appropriate sensors (biological or technical) for at particular robotic task/application
- Must be able to select relevant theories and methods from the fields of robotic sensing and robotic perception and apply these in a new context
- Must be able to communicate the above (using proper terminology), both orally and in a written report
- Must be able to demonstrate a working prototype of their solution

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Robotic Sensing (C)**
***Robot sansning***

Semester. 4

Purpose: The purpose of this course is to equip the student with knowledge and skills within robot sensor technology

Objective: Students who complete the module should have the following knowledge and skills:

Knowledge

- Must have knowledge about how humans sense their surroundings
- Must have knowledge about human sensors related to, touch, force, vibrations and vision
- Must have knowledge about the electromagnetic spectrum, visual light and how such signals can be captured
- Must have knowledge about intensity-, colour-, thermal- and infrared cameras
- Must be able to understand the critical parameters of a camera (focus, focal-length, depth-of-field, shutter, etc.)
- Must be able to understand how distances can be estimated using different sensors
- Must be able to understand how biological signals from humans can be captured

Skills

- Must be able to apply biological and technical sensors in a gives robotic task/application
- Must be able to select and apply the correct illumination in a given robotic task/application
- Must be able to apply filtering to suppress noise in sensor signals
- Must be able to correct a distorted sensor signal
- Must be able to apply calibration in order to align sensor coordinates and robot coordinates

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: As are stated in the Framework Provisions

**Title:** **Robotic Perception (C)**
*Robot perception*

Semester: 4

Purpose: The purpose of this course is to equip the student with knowledge and skills about how to analyse the content of data, especially images and video, and how to make decisions based on the analysis.

Objective: Students who complete the module should have the following knowledge and skills:

Knowledge

- Must have knowledge about the building blocks in a generic classification system
- Must have knowledge about different colour representations
- Must be able to understand the principles of point- and neighbourhood processing
- Must be able to understand what a BLOB is and how it can be extracted
- Must be able to understand how moving objects can be segmented in a video sequence
- Must be able to understand the concept of a multidimensional feature-space.
- Must be able to understand the principle behind Bayes rule and how a classifier can be derived here from
- Must be able to understand how to assess a classification system

Skills

- Must be able to apply point processing methods like grey-level mapping, histogram stretching, thresholding and image arithmetic
- Must be able to apply neighbourhood processing methods like median filter, mean filter and edge detection
- Must be able to apply morphologic operations like erosion, dilation opening and closing
- Must be able to suggest/select relevant features and methods for extracting these
- Must be able to apply Mahalanobis distance
- Must be able to apply dimensionality reduction methods to a feature space

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions.

**Title:** **Probability Theory and Statistics (C)**
*Sandsynlighedsregning og statistik*

Semester: 4

Purpose: After attending the course the students have developed the engineering intuition of the fundamental concepts and results of probability and statistics. They are able to apply the taught material to model and solve simple engineering problems involving randomness.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have knowledge about the concept of probability spaces
- Must have knowledge about the conceptual models of estimation and hypothesis testing
- Must be able to understand the basic concepts of probability theory, i.e., probability of events, random variables, etc.
- Must be able to understand basic concepts of statistics such as binary hypothesis testing.

Skills

- Must be able to apply/compute Bayes rule in simple contexts
- Must be able to determine the probability that Binomial, Poisson, and Gaussian random variables take values in a specified interval
- Must be able to determine the mean and variance of Binomial, Poisson, and Gaussian random variables
- Must be able to determine the marginal distributions of multi-variate Gaussian variables
- Must be able to apply and interpret ML-estimation in simple contexts involving the Binomial, Poisson, and Gaussian distribution
- Must be able to apply and interpret binary-hypothesis tests in simple contexts involving the Binomial, Poisson, and Gaussian distribution

Competencies

- Must be able to apply the general concepts of probability theory and statistics in a new, simple context. This includes choosing suitable methods, evaluating outcomes, and making the appropriate conclusions

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Robot Integration (P)**
***Robot integration***

Semester: 5

Purpose: A robot is a versatile mechanical device equipped with actuators and sensors under the control of software running on a computer system. Mechanically as well as in software and associated algorithms the individual components must be integrated into one robot system. With the exception of controlled environments, it is generally not realistic to anticipate all motions and actions a robot may have to take to accomplish a requested task. It requires robots to take actions automatically and potentially allows the user to declaratively specify what tasks to have performed, not how.

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have an understanding of the interaction between the basic components of a robot system
- Must have an understanding the most common architectures and frameworks for robot control software
- Must have insight into the notion of protocols and data communication used in robot systems
- Must have knowledge of how robots are integrated in a larger context (e.g. in a manufacturing enterprise)

Skills

- Must be able to select and use appropriate robotics software frameworks for a specific robotics task
- Must be able to deliberate on the appointment of functionality to components and architectures for hardware and software

Competencies

- Must have the ability to integrate mechanics, sensors, actuators and associated algorithms and architectures to support the control of a robotics problem
- Must have the ability to develop a dynamic model of a robotics problem
- Must have the ability to design and implement controllers to solve a robotics problem
- Must be able to integrate robots in a larger context (e.g. in a manufacturing enterprise)

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Software and Automation Frameworks (C)**
*Software og automations frameworks*

Semester: 5

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must be able to explain key concepts of networks, including communication protocols and reference models such as OSI and TCP/IP
- Must be able to explain key concept of operating systems, including how programmes communicate internally, access peripheral devices, and handle tasks
- Must have insight into real time aspects of computer software communicating with peripheral devices
- Must be able to explain the fundamentals of typical software systems (e.g. ERP and SCADA systems) found in manufacturing enterprises.
- Must be able to explain the general principles of compilers, parsers and wrappers
- Must be able to explain the general principles and use of PLC's

Skills

- Must be able to identify relevant areas of focus, concepts and methods to assess and develop robot applications that involve networks, basic protocols and distributed systems
- Must be able to apply design tools such as compilers, parsers and wrappers
- Must be able to program and interface to a standard PLC

Competencies

- Must be able to design and implement robotic systems that communicate via network(s)
- Must be able to integrate robotic systems with typical software systems (e.g. ERP, SCADA, PLC) found in a manufacturing enterprise.

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Productions Systems and Automation (C)**
*Produktionssystemer og automation*

Semester. 5

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have an understanding of the basic elements and concepts involved in industrial manufacturing
- Must have knowledge about important material transformation processes
- Must have knowledge about main automation building blocks
- Must understand how the building blocks can be combined into an integrated production system
- Must have an understanding of the relationship between product design and automation (design for automation)
- Must have knowledge about safety issues related to the operation of automatic manufacturing systems
- Must understand benefits of automation in product realization

Skills

- Must be able to formulate operational objectives for the performance of an automatic production facility
- Must be able to develop solution concepts that satisfy requirements specification
- Must be able to identify critical elements of proposed solution concepts
- Must be able to design safe automated production system
- Must be able to justify the benefits of an automatic production system

Competencies

- Must be able to interact and communicate with the participants involved in the design, development and operation of manufacturing systems
- Must have gained awareness and a holistic understanding of automatic manufacturing systems and part of running a production facility

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Robots in the Health Care System (C)**
***Robotter i sundhedssystemet***

Semester: 5

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must be able to account for the ethical aspects related to the use of robotics in the health care system
- Must have knowledge about functional disabilities and their rehabilitation through robotics (e.g. Robotics for Stroke patients, Spinal cord injured patients, etc.)
- Must have knowledge about mental rehabilitation through robotics
- Must have knowledge about robotic control of the human body
- Must have knowledge on the integration of the human body and robots in rehabilitation
- Must have knowledge about haptics and robotics
- Must have knowledge about alternative control methods for assistive robotics (e.g. Brain computer interfaces, tongue computer interfaces and eye based control systems)
- Must have knowledge about service, surgical and social robotics
- Must have knowledge about methods to evaluate the effect of applying robotics in rehabilitation/healthcare

Skills

- Must be able to apply knowledge about the functional effects of diseases for the choice of optimal robotic rehabilitation and robotic assistive technologies
- Must be able to apply knowledge about the effects of aging/injury in order to identify relevant robotic assistive technologies
- Must be able to evaluate and apply robotic technologies in health care
- Must be able to advice people in the health care systems about the use of robotics in rehabilitation and assistive technologies

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **BSc Project (Robots in an Application Context) (P)**
**BSc projekt (*Robotter i en applikations sammenhæng)***

Semester: 6

Purpose: A specific task which potentially can be robotized is selected (e.g. an industrial task, a rehabilitation task, a service task). After the end of the module the student must show capability to develop and present a robotic solution to the task

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must have knowledge of at least one application area, e.g. robots in health care, industry or entertainment
- Must have knowledge of the scientific basis for the specific application area

Skills

- Must be able to make a requirement specification
- Must be able to seek out and develop a solution and present it in the form of sketches, diagrams, drawings and virtual as well as physical prototypes
- Must be able to justify the benefits of the developed solution
- Must be able to independently plan and carry out a development on basis of a given problem
- Must be able to choose and apply relevant methods and tools

Competencies

- Must be able to devise how a relatively complex robotic system could be specified, designed, managed and produced, and in a professional manner to prove this
- Must have the ability to assess important impacts (e.g. economic) aspects of the solution
- Must be able to demonstrate engineering skills within robotics and to display their ability to perform engineering work
- Must be able to take responsibility for their own professional development

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **BSc Project (Robots in a Theoretical Context) (P)**
**BSc projekt (*Robotter i en teoretisk sammenhæng)***

Semester: 6

Purpose: A specific more theoretical problem within robotics is selected (e.g.vision, path planning, human-robot interface).

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- One or more topics from the robotics study program are selected for further investigation. After the end of the module the student must show a much deeper understanding of the selected topics.

Skills

- Must be able to acquire new in depth knowledge related to selected topics with in robotics
- Must be able to present acquired knowledge in the form of mathematics articles, and virtual as well as physical prototypes
- Must be able to plan and carry out a research study on basis of a specific problem
- Must be able to apply and choose scientific methods and tools to research within the chosen area of knowledge
- Must be able to communicate problems, methods and results within the scientific area, in writing and discuss professional and scientific problems with peers

Competencies

- Must be able to demonstrate scientific skills within robotics and to display their ability to perform scientific work
- Must be able to take responsibility for their own professional development

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral examination based on a written report and demonstrations

Evaluation criteria: Are stated in the Framework Provisions

**Title:** **Motion Planning and Path Planning (C)**
*Planlægning af bevægelser og vej*

Objective: Students who complete the module should have the following knowledge, skills and competences:

Knowledge

- Must be able to understand 2D road maps, including visibility graphs and Voronoi diagrams
- Must be able to account for an optimal path in road maps
- Must be able to account for potential fields
- Must be insight into kinematic and holonomic constraints
- Must be able to explain path and trajectory
- Must be able to explain sampling based algorithms

Skills

- Must be able define work space and configuration space of rigid objects
- Must be able to construct simplification of configuration spaces
- Must be able to use grid-based search algorithms
- Must be able to use methods and metrics for evaluation of path tracking
- Must be able to do basic feedback control for path and trajectory tracking

Competencies

- Must be able to design and implement motion and path planning algorithms

Type of instruction: See the general description of the types of instruction described in the introduction to Chapter 3.

Exam format: Oral or written examination. Exam format is decided on by start of semester.

Evaluation criteria: Are stated in the Framework Provisions

## Chapter 4: Entry into Force, Interim Provisions and Revision

The curriculum is approved by the Dean of the Faculty of Engineering and Science and enters into force as of September 2014.

In accordance with the Framework Provisions and the Handbook on Quality Management for the Faculty of Engineering and Science and The Faculty of Medicine at Aalborg University, the curriculum must be revised no later than 5 years after its entry into force.

## Chapter 5: Other Provisions

### 5.1 Rules concerning written work, including the Bachelor's project

In the assessment of all written work, regardless of the language it is written in, weight is also given to the student's formulation and spelling ability, in addition to the academic content. Orthographic and grammatical correctness as well as stylistic proficiency are taken as a basis for the evaluation of language performance. Language performance must always be included as an independent dimension of the total evaluation. However, no examination can be assessed as 'Pass' on the basis of good language performance alone; similarly, an examination normally cannot be assessed as 'Fail' on the basis of poor language performance alone.
The Board of Studies can grant exemption from this in special cases (e.g., dyslexia or a native language other than Danish).

The Bachelor's project must include an English summary.[1] If the project is written in English, the summary must be in Danish.[2] The summary must be at least 1 page and not more than 2 pages (this is not included in any fixed minimum and maximum number of pages per student). The summary is included in the evaluation of the project as a whole.

### 5.2 Rules concerning credit transfer (*merit*), including the possibility for choice of modules that are part of another programme at a university in Denmark or abroad

In the individual case, the Board of Studies can approve successfully completed (passed) programme elements from other Master's programmes in lieu of programme elements in this programme (credit transfer). The Board of Studies can also approve successfully completed (passed) programme elements from another Danish programme or a programme outside of Denmark at the same level in lieu of programme elements within this curriculum. Decisions on credit transfer are made by the Board of Studies based on an academic assessment. See the Framework Provisions for the rules on credit transfer.

### 5.3 Rules concerning the progress of the Bachelor's programme

The student must participate in all first year examinations by the end of the first year of study in the Bachelor's programme, in order to be able to continue the programme. The first year of study must be passed by the end of the second year of study, in order that the student can continue his/her Bachelor's programme.

In special cases, however, there may be exemption from the above if the student has been on a leave of absence. Leave is granted during first year of study only in the event of maternity, adoption, military service, UN service or where there are exceptional circumstances.

### 5.4 Rules concerning the completion of the Bachelor's programme

The Bachelor's programme must be completed no later than six years after it was begun.

[1] Or another foreign language (French, Spanish or German) upon approval by the Board of Studies.
[2] The Board of Studies can grant exemption from this.

**5.5 Special project process**
In the 3rd, 4th and 5th semesters, the student can upon application, design an educational programme where the project work is replaced by other study activities; cf. the Framework Provisions section 9.3.1.

**5.6 Rules for examinations**
The rules for examinations are stated in the Examination Policies and Procedures published by the Faculty of Engineering and Science on their website.

**5.7 Exemption**
In exceptional circumstances, the Board of Studies study can grant exemption from those parts of the curriculum that are not stipulated by law or ministerial order. Exemption regarding an examination applies to the immediate examination.

**5.8 Rules and requirements for the reading of texts**
It is assumed that the student can read academic texts in his or her native language as well as in English and use reference works etc. in other European languages.

**5.9 Additional information**
The current version of the curriculum is published on the Board of Studies' website, including more detailed information about the programme, including exams.